Scattering of Baroclinic Long Waves by Complex Coastal Topography: An Application of an Isopycnal Model

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LONG-TERM GOALS

The long-range objective of this work is to understand the role of complex bathymetry, non-linearity and boundary layers on the dynamics of flow in the coastal ocean.

OBJECTIVES

The objective of this work is to examine long period processes on the continental slope using an isopycnal numerical model and the California Bight as a case study. The model is used to study the response to complex bathymetry of remotely forced baroclinic disturbances with periods of 20 to 30 days. A series of idealized model runs are performed to investigate progressively more complex bathymetry and coastline geometry, using a detailed existing set of observations from the southern California Bight for model initialization and evaluation. The work provides a robust test of a new model for the coastal ocean. In addition, the sources of the disturbances in this frequency band are being explored.

APPROACH

Many coastal modeling studies in the last three decades have carefully avoided regions of complex topography. This can be done with some success when studying processes over the shelves. However, the continental slope is indented by submarine canyons, offshore ridges, and banks.

In the southern California Bight energetic long period (20-30 d) fluctuations dominate the variances in the coastal flow field over the continental slope. Coastal sea level data south of this region are consistent with propagation speeds of a first mode CTW (coastal trapped wave). Current meter data suggest that these disturbances enter the coastal basins within the Bight from the southeast and appear to pivot counterclockwise around the basin, so that some portion of the energy exits the basin over the western sill, whereas the remainder passes into the Santa Barbara Channel. The phase speed of the disturbances is reduced by an order of magnitude as the waves propagate around the basin. One of the issues to be examined in this work is how the disturbances transit through the topographically complex California Bight--do they pass through the Santa Barbara Channel or do they bypass it by turning offshore south of the channel (or does some portion of the energy go in each direction)?

Model studies suggest that scattering of CTWs by irregularities in the topography such as abrupt widening or narrowing of the shelf, or the existence of submarine canyons can cause dramatic alterations in the structure of coastal circulation patterns. In most situations, the energy of an incoming single mode wave is scattered into several higher modes, so that the spatial and temporal structure of the current field is significantly altered by the interaction with the topography. We address here the problem of disturbances propagating freely along the slope as they encounter a strong topographic change, in this case, an abrupt widening. Along the US west coast sharp widenings occur frequently over the continental slope; for example, near Point Conception, Cape, Mendocino and the Strait of Juan de Fuca. The model is tested in the southern California Bight, where the continental shelf has an abrupt change in orientation (~90 degrees) as it encounters the Santa Barbara Channel, in an area for which an extensive data set exists. The data are sufficient to provide initial conditions such as stratification and sea level fluctuations as well as to allow model evaluation.

We have taken two approaches in the study, first we examine the sources of the disturbances in the 20 to 30 day period band; second we explore how disturbances navigate the complex bathymetry at the California Bight. This particular problem, while relevant to important processes on continental slopes, will also allow testing of the isopycnal numerical model in a coastal oceanographic setting.

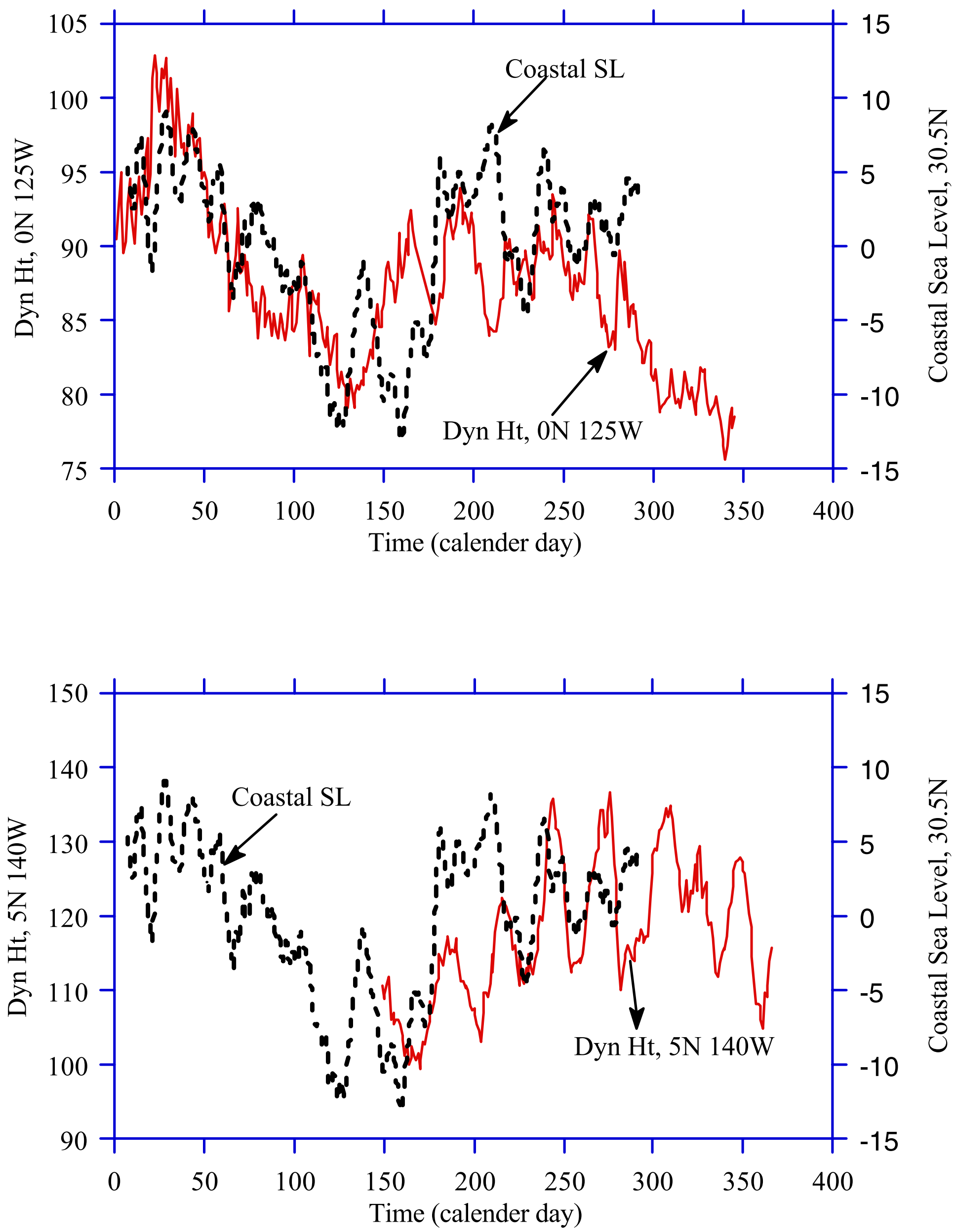
WORK COMPLETED

a) ***Origin of the disturbances.*** The long period, poleward propagating disturbances being modeled in this project are responsible for a majority of the velocity and temperature variance in coastal regions of the southern California Bight. Our model studies (see Section b) to date demonstrate that some energy passes through the Bight, where it might then propagate along much of the US west coast as an important source of variance in coastal currents.

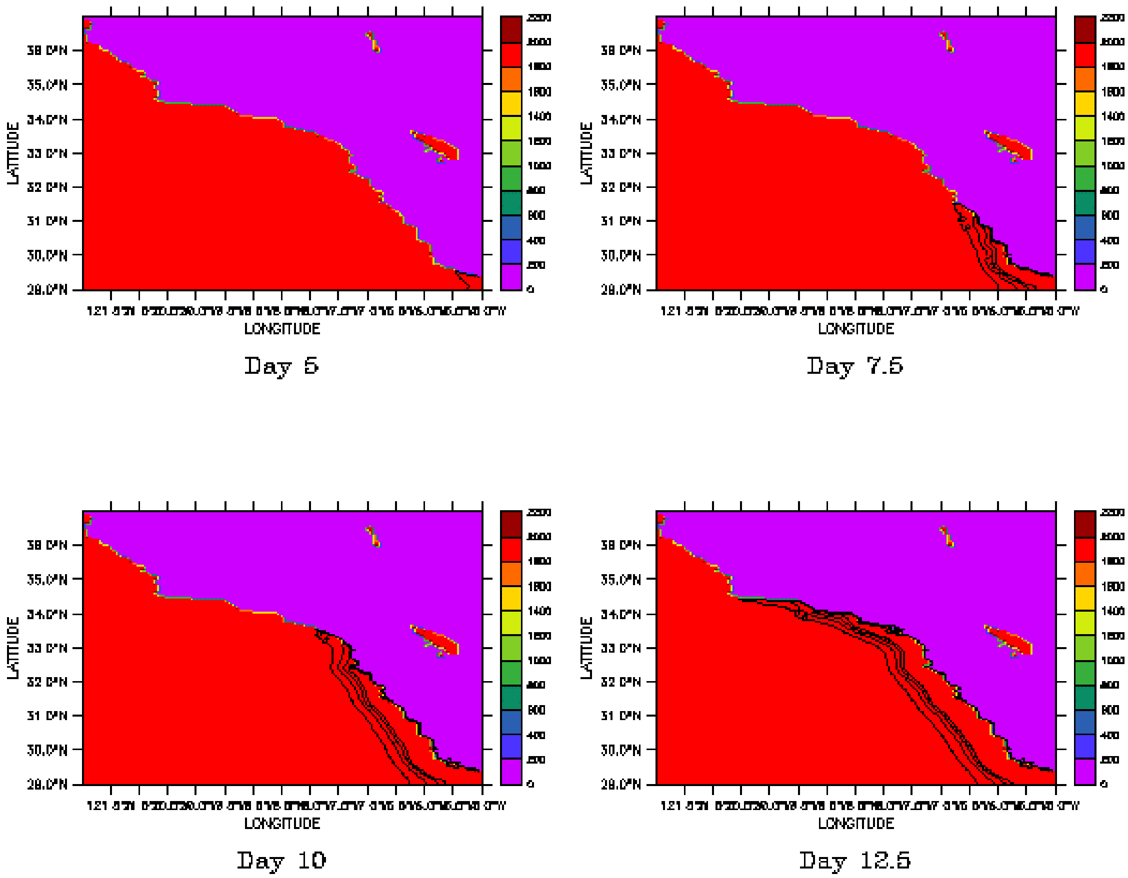
The disturbances have several characteristics in common with so called "Tropical Instability Waves" (TIWs); in particular, period (20-30 d), seasonal cycle (maximum variance in fall and winter) and a subsurface maximum in variance (~100-200 m). The energy of these waves travels eastward and poleward across the Pacific as Rossby/gravity waves, impinging on the North American coast somewhere south of about 20 N. Sea level records examined to date suggest that the origin of the disturbances is at least several hundred kilometers south of the Bight. To explore possible connections between tropical instability waves and the coastal disturbances, dynamic height time series from the Equatorial Pacific TAO array were compared to coastal sea level data along North America during 1988, the year when our prior coastal analysis was performed. Results are highly encouraging--time series have the same frequency content and seasonal cycle (Fig. 1). However, because of the long signal period, only a few examples occur in any one year. Also, available model studies give energy propagation speeds ranging from 5 to 200 cm/sec. Thus, it is difficult to definitively derive a relationship between observed equatorial and coastal signals. Because the possibility of a direct connection between equatorial and coastal processes is highly relevant for model studies of the Pacific Ocean, we will continue to explore this connection by expanding our data to 5 years (1986-1990), the period when we have comprehensive current data within the southern California Bight.

b) Model results. The model domain encompasses the California Bight, with the southern boundary off the coast of Baja, and the northern boundary north of Point Conception. The model was forced by interface displacements with a first baroclinic mode structure in the southeast corner of the domain and was run with 8 layers. The model is run as an initial value problem for 25 days, before the disturbance has had enough time to propagate completely around the basin. Since the region is small, high spatial resolution is used (3km). The CTW thus generated propagates up the coast and encounters the bend in the coastline. Linear theory can predict scattering from simple changes in coastline, but a numerical model is needed to examine the scattering process when the bathymetry is complex. Results from two model runs are shown, one with a flat bottom (Fig. 2), and one with complex bathymetry (Fig 3.). The differences between the two model runs are striking. In particular, more rapid phase propagation in the run with bathymetry included is apparent. This result is predicted from linear CTW theory. This simulations also shows that the disturbance first travels inshore of the Channel Islands along the coast, with another propagation pathway on the inshore side of the islands. This gives the apparent reduction in phase speed seen in the observations. The small trapping scales over the slope also agrees with the observations. More detailed model/observation comparisons are continuing.

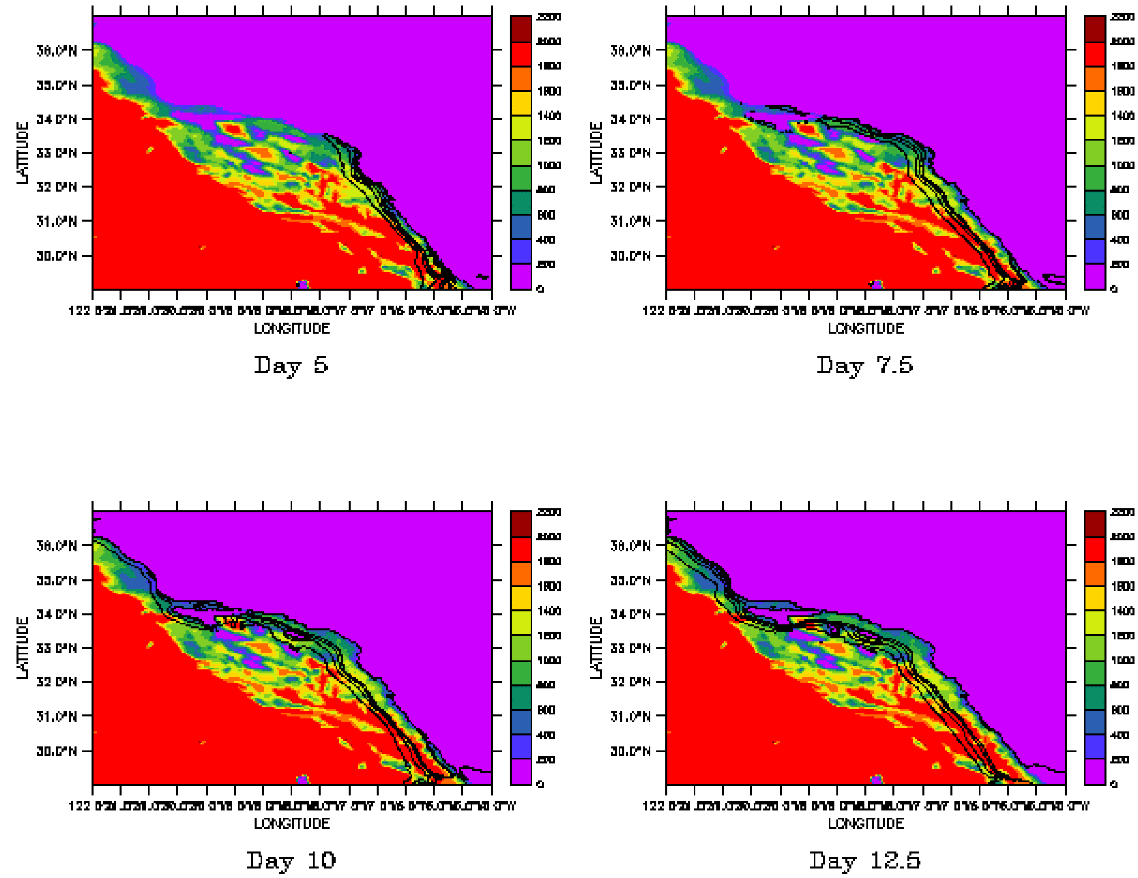
In the next year, the forcing of the model will be modified to attempt to reproduce the subsurface maximum in velocity. A detailed analysis of scattering near the channel islands will be examined, and a detailed calculation of energy loss resulting from scattering will be made. In particular, the percentage of energy that passes through the Bight to provide a source of variance for regions north of the Bight will be estimated.



1. Comparison of coastal sea level off Baja California and dynamic height from two locations, one on the equator and one at 5 N in 1988. The similarity in energy content suggests a possible mechanistic connection between the two disturbances.



2. Shown is coastal outline and interface 3 displacement (contour interval is 0.5 m) for a flat bottom simulation at 5 to 12.5 days.



3. Same as for 2 with bathymetry included.

RESULTS

Our results to date include the following: 1) compelling evidence for a connection between the 20-30 day disturbances in the California Bight to TIWs has been compiled, 2) we have shown that the observed slowing of disturbances as they pass through the Bight can be explained by the dynamics of a CTW interacting with the complex topography, and 3) we have shown that a significant amount of energy is able to pass Point conception, contrary to some previous ideas about energy propagation. Both the observational and modeling studies suggest that long period motions are able to easily propagate through the complex topography and northward up the coast with little dissipation of energy from scattering.

IMPACTS/APPLICATIONS

The impact of our results is to improve coastal ocean simulations by demonstrating the importance of the inclusion of remote forcing. In addition, the successful demonstration of the application of the isopycnal model to a coastal problem will encourage its use for other applications.